CLAIMS

1. A method for producing multiple quantum well intermixed (QWI) regions having different bandgaps on a single substrate, comprising the steps of:

forming a substrate comprising one or more core layers defining at least one quantum well;

depositing a succession of intermixing barrier layers over the quantum well, each successive intermixing barrier layer being formed of a semiconductor material and having a different etch characteristic than an immediately preceding barrier layer;

etching away different numbers of the successive barrier layers in different regions of the substrate so as to provide different total thicknesses of barrier layer in different regions of the substrate; and

applying an intermixing agent to the surface of the substrate such that the degree of intermixing in the quantum well region varies as a function of the total thickness of barrier layer, thereby forming different bandgaps in the quantum well in each of the respective regions.

2. The method of claim 1 in which the step of depositing the intermixing barrier layers comprises epitaxial growth.

3. The method of claim 1 or claim 2 in which the intermixing barrier layers each comprise substantially single crystal semiconductor layers.

4. The method of any one of claims 1 to 3 in which the steps of forming the substrate and depositing the intermixing barrier layers are carried out in the same epitaxial growth equipment.

5. The method of claim 1 in which the step of applying an intermixing agent to the surface of the substrate comprises bombarding the substrate with high energy ions in an ion implantation process.

6. The method of any one of claims 1 to 4 in which the step of applying an intermixing agent to the surface of the substrate comprises depositing a QWI cap layer onto the substrate, the QWI cap layer initiating or promoting intermixing.

7. The method of any preceding claim further including the step of activating the intermixing agent.

8. The method of claim 7 in which the step of activating the intermixing agent comprises thermally processing the substrate after delivering the intermixing agent to the substrate.

9. The method of claim 1 in which the barrier layers alternate between two different material types.

10. The method of claim 1 in which the barrier layers are grouped in pairs, each of the respective regions having a different number of pairs of barrier layers.

11. The method of any preceding claim in which the quantum well region is formed from an aluminium quaternary indium phosphide material.

12. The method of any preceding claim in which the intermixing barrier layers include successive layers of indium phosphide (InP) and indium gallium arsenide (InGaAs).

13. The method of claim 12 in which the etching step comprises etching the InGaAs layers in $H_3PO_4 : H_2O_2 : H_2O$ and etching the InP layers in $HCl : H_2O$.

14. The method of claim 12 in which the etching step comprises etching the InGaAs layers in $H_2SO_4 : H_2O_2 : H_2O$ and etching the InP layers in $HCl : H_3PO_4$.

15. The method of any preceding claim in which the quantum well is formed from an aluminium ternary gallium arsenide material.

16. The method of any one of claims 1 to 11 in which the intermixing barrier layers include successive layers of gallium arsenide (GaAs), aluminium gallium arsenide (AlGaAs) or aluminium arsenide (AlAs).

17. The method of claim 16 in which the etching step comprises etching the GaAs layers in $H_2SO_4 : H_2O_2 : H_2O$ and etching the AlGaAs/AlAs layers in a buffered HF solution.

18. The method of claim 1 further comprising the step of planarizing the substrate after the applying the intermixing agent.

19. The method of claim 18 in which the planarizing step comprises removing one or more of the intermixing barrier layers from the surface of the substrate.

20. The method of claim 19 in which the planarizing step comprises removing all of the intermixing barrier layers from the surface of the substrate.

21. The method of claim 1 in which the step of depositing the succession of intermixing barrier layers comprises:

depositing a first intermixing barrier layer onto the substrate over said quantum well region, the first barrier layer being formed of a semiconductor material having a first etch characteristic;

depositing a second intermixing barrier layer onto the substrate over said first barrier layer, the second barrier layer being formed of a semiconductor material having a second etch characteristic; and

etching away the first and second barrier layers in first regions of the substrate and etching away the second barrier layer in second regions of the substrate and leaving the first and second barrier layers in other regions of the substrate;

such that after applying the intermixing agent to the surface of the substrate, different bandgaps in the quantum well region are respectively formed in each of the first regions, the second regions and the other regions.

22. The method of claim 21 in which the step of depositing further includes depositing a third intermixing barrier layer onto the substrate prior to depositing the first and second barrier layers, the third barrier layer being formed of a semiconductor material having a third etch characteristic; and

in which the etching step includes etching away the first, second and third barrier layers in third regions of the substrate;

such that after applying the intermixing agent to the surface of the substrate, different bandgaps in the quantum well region are respectively formed in each of the first regions, the second regions, the third regions and the other regions.

23. The method of claim 22 in which the third etch characteristic is the same as the second etch characteristic.

24. The method of claim 1 in which the step of depositing the succession of intermixing barrier layers comprises:

depositing a first and second intermixing barrier layers onto the substrate over said quantum well region, the first and second barrier layers being formed of semiconductor material and respectively having first and second etch characteristics;

depositing a third and fourth intermixing barrier layers onto the substrate over said first and second barrier layers, the third and fourth barrier layers being formed of semiconductor material and respectively having third and fourth etch characteristics;

etching away the first, second, third and fourth barrier layers in first regions of the substrate and etching away the third and fourth barrier layers in second regions of the substrate and leaving the first, second, third and fourth barrier layers in other regions of the substrate;

such that after applying the intermixing agent to the surface of the substrate, different bandgaps in the quantum well region are respectively formed in the first regions, the second regions and the other regions.

25. The method of claim 6 in which the QWI cap layer comprises an impurity rich material.

26. The method of claim 25 in which the impurity comprises one or more of sulphur, zinc, silicon, fluorine, copper, germanium, tin and selenium.

27. The method of claim 25 or claim 26 in which the impurity-rich material comprises silica doped with one or more of the impurities sulphur, zinc, silicon, fluorine, copper, germanium, tin and selenium.

28. The method of claim 6 in which the QWI cap layer is sputter deposited.

29. The method of claim 18 further including the steps of:

depositing a succession of planarization layers beneath the succession of intermixing barrier layers, the succession of planarization layers identical in number of layers and layer materials to the first succession of barrier layers, but having a total thickness substantially less than the total thickness of the first succession of intermixing barrier layers;

planarizing the substrate by successively removing intermixing barrier layers and corresponding planarization layers in a series of selective etches.

30. A wafer of epitaxially grown material comprising a mechanically supporting substrate, one or more layers defining a quantum well structure deposited thereon, and a succession of intermixing barrier layers formed over the quantum well structure, each successive intermixing barrier layer being formed of a semiconductor material having a different etch characteristic than an immediately preceding barrier layer so that each successive layer can act as an etch stop layer to an immediately preceding higher layer.

31. The wafer of claim 30 in which the intermixing barrier layers are alternating in etch characteristic.

32. The wafer of claim 30 or claim 31 in which the intermixing barrier layers are arranged in adjacent pairs, at least one of the barrier layers of each pair providing a substantial resistance to migration of QWI-initiating agent.

33. The wafer of any one of claims 30 to 32 including a first succession of barrier layers having a first total thickness, and a second succession of planarization layers identical in number of layers and layer materials to the

first succession of barrier layers, but having a second total thickness substantially less than the first total thickness.

34. The wafer of claim 33 in which the second total thickness is more than an order of magnitude less than the first total thickness.

35. A semiconductor optical device manufactured using the process of any one of claims 1 to 29.

36. A method substantially as described herein with reference to the accompanying drawings.